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TOW MISSILE STRESS CORROSION STUDY (RING SPECIMENS)

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ABSTRACT

This report addresses a stress corrosion study on 300 grade, 18% cobalt-containing maraging steel (C-300) and 250 grade, cobalt-free maraging steel (T-250) TOW missile motor cases. In the early 1980's, cobalt became a strategic element which ~~This~~ eventually led to the ~~implementation of the~~ use of T-250, in place of C-300 in this missile system. This report attempts to establish relative differences in stress corrosion susceptibility between the two materials in the component fabricated condition.

The specimens used in this study were ring-type specimens, which were machined from along the length of the actual rocket motor cases. Each specimen was notched, precracked, and tested in a salt water environment. Load versus time-to-failure data was obtained. Also investigated was the possible effects of residual stress on the load versus time-to-failure data.

Results indicate significant scatter in the data, which could be attributed to the residual stresses along the length of the rocket cases. There was no significant difference in time-to-failure between the two steels. Keywords: Split D rings; Maraging steels. (edc)

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INTRODUCTION/BACKGROUND

In 1984, the U.S. Army Missile Command (MICOM) requested the U.S. Army Materials Technology Laboratory (MTL) to do a feasibility study on obtaining fracture toughness values (K_{Ic}) on TOW rocket motor cases. The wall thickness of the missile motor case (0.072 inch) was found to be too thin for obtaining a valid fracture toughness value. Therefore, only a fracture toughness indicator (K_q) could be addressed. In order to obtain K_q values, the cylinders were pre-cracked using a method developed by MTL. This method involved the use of a series of ring specimens taken from four TOW missile cases fabricated by the shear spinning method. The specimens were electrodischarge machined (EDM) to a depth that did not penetrate the cylinder wall. The ring specimens were then subjected to a slowly increasing internal pressure until the crack propagated through the cylinder wall causing specimen failure. All loads and deflections were recorded. However, no relative values for fracture toughness could be determined. The results of the testing displayed the need for further study of this problem.

Since the notch sensitivity was important, a test to determine this criterion for the missile case was undertaken before any other testing for material properties could be accomplished. A notch running across the face or width was machined into each of the specimens. The notch depth of a number of ring specimens was varied (i.e., specimen 1 had a notch depth of 0.020 inch, specimen 2 had a notch depth of 0.025 inch, etc.). These specimens were then tested with the notch in tension using a split "D" ring test fixture (Figure 1). A constant deadweight load was applied to the fixturing using a load rupture machine (Figure 2). This test not only gave an indication of the material's notch sensitivity, but also indicated that there may be significant residual stresses in the missile cases. These residual stresses may have some effect on the material fracture toughness.

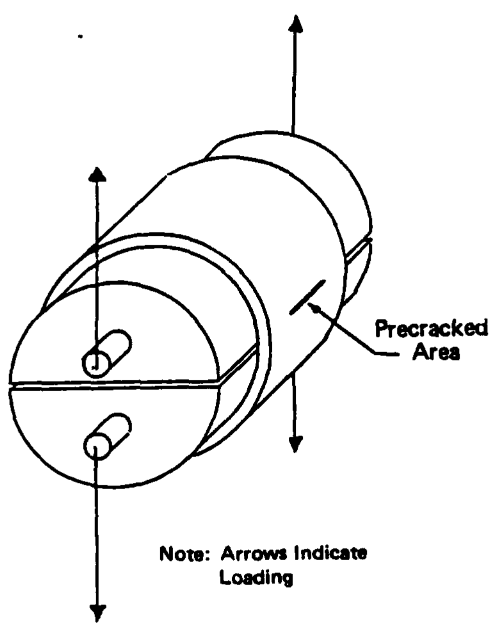

Figure 1. Split "D" ring test fixture with specimen.

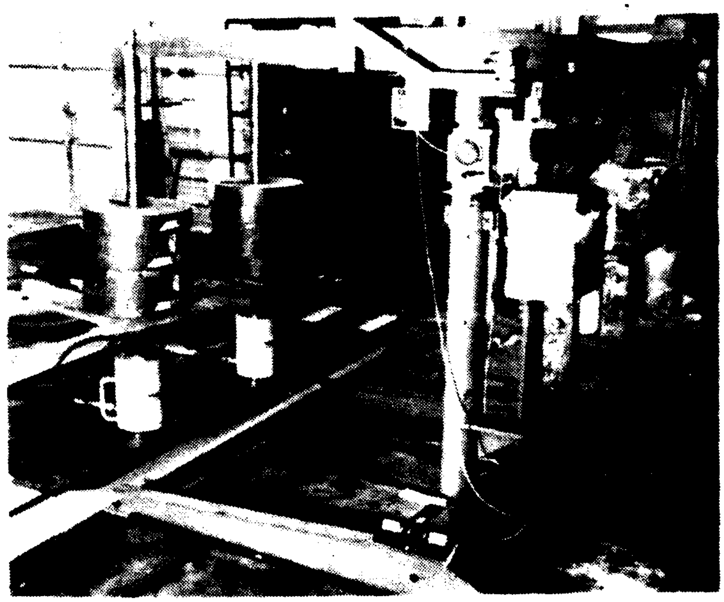

Figure 2. Load rupture machine.

In 1987, a study on the stress corrosion susceptibility of the material used in the TOW missile motor cases was initiated. Two types of stress corrosion tests were performed. The cantilever bend-type specimen was used to define the susceptibility to stress corrosion cracking (K_{Iscc}) in plate form for the C-300 and T-250 material. The results of that work are reported by Scanlon and Hickey of MTL.* This report addresses the relative susceptibility to stress corrosion cracking of fabricated missile cases using the previously described ring-type specimens. The specimens were tested in a 3.5% sodium chloride (NaCl) distilled water solution with load versus time data being obtained.

The possibility of residual stresses playing a major role in the time-to-failure data was considered. An attempt to measure the residual stresses acting on the rings was made using nondestructive techniques. American Stress Technologies, Inc. of Pittsburg, PA, performed a series of Barkhausen noise tests for MTL. These rings were supplied to MTL by MICOM. Adjacent rings were destructively tested for residual stresses by MICOM using a milling machine and a strain gage rosette.

TEST PROCEDURE

A total of four cases were cut into cylindrical ring specimens. Two of the missile cases were fabricated from T-250 cobalt-free maraging steel and the remaining two cases were fabricated from C-300 cobalt-containing maraging steel. Ten one-inch-wide specimens were cut from each case (Figure 3). This provided 20 T-250 ring specimens and 20 C-300 ring specimens for testing. A slot, 0.50 inch in length and 0.025 inch in depth, was centered across the width of each specimen using an EDM machining process. The purpose of this notch was to initialize the propagation of a crack in the specimen. To propagate the crack, each specimen was internally pressurized with an oil and water solution. This internal pressure applied to the cylinder walls provided the necessary means for generating the hoop stresses needed to propagate the crack. The pressure was cycled between 500 psi and 3000 psi at a frequency of 15 Hz until a through-wall crack developed causing a loss of internal pressure. Once the specimen was precracked in this manner, it was then statically loaded in the load rupture machine with the crack in tension until it failed.

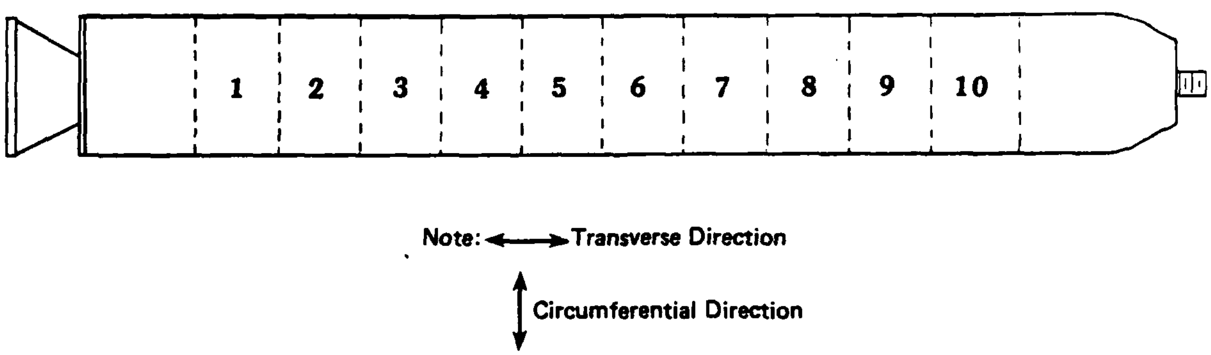

Figure 3. Location of specimens from motor case.

*SCANLON, J. F., and HICKEY, C. F., Jr. "Stress Corrosion Cracking of Maraging Steels," report being processed.

The load rupture machine has two separate split "D" ring fixtures, making it capable of testing two specimens at the same time and recording their times-to-failure as a function of the constant load. A specimen is placed into the split "D" ring fixture which is located within the salt bath. The tensile load is applied to the specimen using the mechanical lever principal which employs a beam with a deadweight on one end. Due to the location of the fulcrum point of the beam, the specimen is loaded with a weight equal to eight times the applied deadweight load.

EXPERIMENTAL RESULTS

The results from the stress corrosion tests indicate no appreciable difference between the T-250 and C-300 steels. Figure 4 shows that both steels behave the same as a function of the same load. The time-to-failure did not significantly change between the two materials.

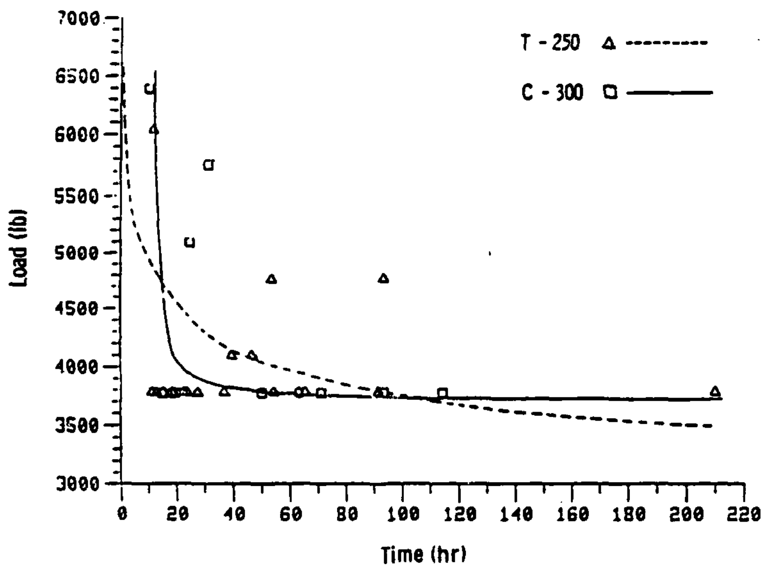

Figure 4. Stress corrosion of T-250 and C-300 steel ring specimens.

Tables 1 and 2 display the actual numbers for the load versus time-to-failure. For the T-250, the average time-to-failure was 48.5 hours while the C-300 had an average time-to-failure of 58.6 hours. These averages include the results of 15 specimens from each material group of 20 specimens. The first five specimens from each group were used to establish a load versus time-to-failure data base. The loads for the T-250 (3776 lb) and C-300 (3768 lb) were chosen as a base for the average time-to-failure at 50 hours. Each specimen was examined after failure and the percent precracked area was calculated. The average percent precrack area of both materials was within 2 to 3 percent. This was the basis for taking the average times-to-failure as the governing criterion for the comparison of both materials.

Typical fracture surface appearances of failed specimens are displayed in Figures 5 and 6. The C-300 typically showed a textured fracture appearance while the T-250 had little or no textured appearance.

Table 1. STRESS CORROSION DATA
T-250 MARAGING STEEL

Load (lb)	Time (hr)
6030	11.7
4752	93.0
4752	53.5
4088	46.5
4088	39.5
3776	209.4
↓	53.9
	90.8
	18.1
	62.9
	65.1
	36.7
	22.2
	11.4
	15.0
	27.3
	12.9
	23.5
	10.8

Table 2. STRESS CORROSION DATA
C-300 MARAGING STEEL

Load (lb)	Time (hr)
5744	221.5
6384	10.1
5744	31.1
5088	24.7
3768	93.1
↓	113.7
	70.5
	63.1
	18.4
	18.5
	14.8
	49.9
	19.6
	71.1

Figure 5. Fracture surface appearance - C-300.

Figure 6. Fracture surface appearance - T-250.

When the failed specimens were examined, an offset in the fracture was observed. One explanation for this offset was due to the possibility that large residual stresses were present. If these stresses are of a tensile nature and are acting on the notch, premature failure due to stress corrosion may take place. Measurement of these stresses could be made using a nondestructive testing technique called the Barkhausen noise method. In using this method, a probe (coil) is placed in contact with the surface of the specimen. The probe emits a magnetic field that measures the alignment of the lattice structure. This nondestructive evaluation (NDE) technique was performed by American Stress Technologies, Inc. on specimens provided by MTL. Tables 3 and 4 are those results of the testing as function of depth. The tables do not provide actual stress values, but show increases and decreases in the noise level as the stresses change magnitudes. Actual stress values could be obtained if a calibration specimen was available. These noise levels do show a similar stress pattern, however, with those obtained by the residual stress measurement techniques used at MICOM.

Table 3. MEASUREMENT OF RESIDUAL STRESS - SMALL RING (BARKHAUSEN NOISE METHOD)

Location	Depth* (mm)	Direction of Scan	Attenuation (dbm)	Stress Type
OD	0.02	Transverse	24.2	Compression
	0.07	Transverse	11.1	Compression
	0.02	Circumferential	35.0	Low Compression
	0.07	Circumferential	72.0	Tension
ID	0.02	Transverse	62.0	Low Tension
	0.07	Transverse	100.0	Tension
	0.02	Circumferential	9.8	Compression
	0.07	Circumferential	7.4	Compression

*Conversion factors: 0.02 mm = 0.0008 in., 0.07 mm = 0.0030 in.

Table 4. MEASUREMENT OF RESIDUAL STRESS - LARGE RING (BARKHAUSEN NOISE METHOD)

Location	Depth* (mm)	Direction of Scan	Attenuation (dbm)	Stress Type
OD	0.02	Transverse	21.0	Compression
	0.07	Transverse	9.0	Compression
	0.02	Circumferential	50.0	No Stress
	0.07	Circumferential	82.0	Tension
ID	0.02	Transverse	83.0	Tension
	0.07	Transverse	55.0	No Stress
	0.02	Circumferential	11.0	Compression
	0.07	Circumferential	8.0	Compression

*Conversion factors: 0.02 mm = 0.0008 in., 0.07 mm = 0.0030 in.

SUMMARY AND CONCLUSIONS

This report contains the results of a qualitative investigation as to the susceptibility to stress corrosion cracking between the C-300 and T-250 TOW missile motor cases. Load versus time data was obtained from ring-type specimens which were machined from missile cases of both materials, and tested in a 3.5% NaCl environment. The effect of residual stress on the time-to-failure data is also addressed. The conclusions are as follows:

1. Time-to-failure data indicates no appreciable difference between the T-250 and C-300.

2. The residual stresses in the rocket motor cases in the vicinity of the cracks may have played a role in time-to-failure in the corrosive environment.

3. A larger population of specimens is needed to better determine differences between the two materials.

4. A fracture toughness math model for thin-walled cylinders should be developed.

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Split "D" ring

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